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# Discussion paper

## THE DARK SIDE OF BANK WHOLESALE FUNDING

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# The Dark Side of Bank Wholesale Funding

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## Abstract

Commercial banks increasingly use short-term wholesale funds to supplement traditional retail deposits. Existing literature mainly points to the "bright side" of wholesale funding: sophisticated financiers can monitor banks, disciplining bad ones but refinancing solvent ones. This paper models a "dark side" of wholesale funding. In an environment with a costless but imperfect signal on bank project quality (e.g., credit ratings, performance of peers), short-term wholesale financiers have lower incentives to conduct costly information acquisition, and instead may withdraw based on negative but noisy public signals, triggering inefficient liquidations. We show that the "dark side" of wholesale funding dominates the "bright side" when bank assets are more arm's length and tradable (leading to more relevant public signals and lower liquidation costs): precisely the attributes of a banking sector with securitizations and risk transfers. The results shed light on the recent financial turmoil, explaining why some wholesale financiers did not provide market discipline ex-ante and exacerbated liquidity risks ex-post.

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# 1 Introduction

Commercial banks increasingly borrow short-term wholesale funds to supplement traditional retail deposits (Feldman and Schmidt, 2001) as a result of intense competition for household savings from alternative investment institutions (mutual funds, life insurance products, etc.). In response to funding shortage, banks tap into wholesale funding markets to attract liquidity surpluses of nonfinancial corporations, households (via money market mutual funds), other financial institutions, state and local authorities, and foreign entities. Such wholesale funds are usually raised on a short-term rollover basis with instruments such as Jumbo CDs (large-denomination certificates of deposit), repurchase agreements (Repo), fed funds, commercial paper, eurodollar deposits, and large brokered deposits.

How would this change in funding structure affect bank risks? The existing literature mainly points to the "bright side" of wholesale funding: more fully exploiting valuable investment opportunities without being constrained by the local deposit supply; the ability of wholesale financiers to provide market discipline (Calomiris, 1999) and to refinance unexpected retail withdrawals (Goodfriend and King, 1998).

However, the credit market turmoil that started in 2007 revealed a "dark side" of wholesale funding. Banks can use wholesale funds to aggressively expand lending and compromise credit quality, particularly when financiers exercise insufficient market discipline. Later, at the refinancing stage, there is a risk of wholesale financiers abruptly withdrawing upon a hint of negative news, triggering inefficient liquidations. When wholesale withdrawals follow a market-wide signal, correlated bank failures may exacerbate systemic risk.

This paper attempts to reconcile the traditional view on the virtues of wholesale funding with the recent experience. We suggest that wholesale funding is beneficial when informed, but exacerbates inefficiencies and can create severe liquidity risks when uninformed. We then ask:

- What are the incentives for short-term wholesale financiers to invest in the acquisition of information on bank project quality?
- What are the incentives for wholesale financiers at the refinancing stage to roll-over funding or to force a bank into liquidation, particularly if they are uninformed?
- What are the optimal contractual arrangements for short-term wholesale funds (e.g., their creditor seniority vis-a-vis long-term funds, such as core retail deposits)?
- What are the private incentives for banks to use short-term wholesale funds, and could they diverge from socially optimal ones?

We consider a bank that finances a risky long-term project with two sources of funds: retail deposits and wholesale funds. Retail deposits are sluggish, insensitive to risks (partly because they are insured), and provide a relatively stable source of long-term funding.<sup>1</sup> Wholesale funds are relatively sophisticated and have the capacity to acquire information on bank project quality. However, they are short-term: provided on a rollover basis and have to be refinanced before final returns realize or the bank will be forced into liquidation.

Our modelling approach is based on Calomiris and Kahn (1991, hereafter CK). We take CK as a benchmark of the “bright side” of wholesale funding. CK show that “sophisticated” wholesale financiers add value through their capacity to monitor banks and to impose market discipline (force liquidations) on loss-making ones. Moreover, they show that monitoring incentives of wholesale financiers are maximized when they are senior at refinancing stage, because it allows them to internalize the benefits of monitoring (payoffs in early liquidations).

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<sup>1</sup>The “sluggishness” of retail deposits is a well-established stylized fact (Feldman and Schmidt, 2001; Song and Thakor, 2007). Retail deposits are typically insured by the government. Their withdrawals are motivated mostly by individual depositors’ liquidity needs and thus are predictable based on the law of large numbers. Although some accounts are formally demandable, retail deposits are “sluggish” because of the transaction services retail depositors received from the banks and the high switching costs (Sharpe, 1997; Kim, Klinger, and Vale, 2003). They therefore provide a relatively stable source of long-term funds. However, the local retail deposit base is considered quasi-fixed in size, as it is prohibitively expensive to expand in the medium term (Flannery 1982; Billett and Garfinkel, 2004). When the deposit supply is not sufficient to fund all available investment opportunities, banks can choose to attract, in addition, wholesale funds from sophisticated institutional investors.

In practice, short-term wholesale funds indeed enjoy *de facto* (effective) seniority because of the first-come-first-served sequential service rule and the relative sluggishness of insured retail depositors. This was the main reason that in almost all recent bank failures (e.g., Continental Illinois, Northern Rock, IndyMac) short-term wholesale financiers were able to exit well ahead of retail depositors without incurring significant losses themselves. Interestingly, the well-publicized retail depositor run on Northern Rock took place only after the bank had already nearly exhausted its liquid assets to pay off the exit of short-term wholesale funds (Shin, 2008; Yorulmazer, 2008).<sup>2</sup>

We then introduce into the benchmark CK model a single novel feature: *a costless but noisy* public signal on bank project quality. This represents public information that wholesale financiers can costlessly process and that is a noisy proxy for bank-specific fundamentals. Examples include market prices or credit ratings for traded assets (e.g., mortgage-backed securities), performance of other similar banks, or various market- or sector-wide indicators (e.g., house or energy prices). Wholesale financiers may use the public signal when costly private monitoring does not produce sufficiently precise information on bank fundamentals (because of either low investment in monitoring or merely bad luck).

We show that this minor and plausible change to the CK setup can under some conditions lead to outcomes consistent with the "dark side" of wholesale funding seen in recent events. In our model, the presence of a costless but noisy signal:

- Lowers the incentives of wholesale financiers to monitor;
- Gives wholesale financiers excess incentives to liquidate banks based on overly noisy public information; and
- Importantly, those distortions become stronger when wholesale financiers are *more*

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<sup>2</sup>Marino and Bennett (1999) analyze six major bank failures in the US between 1984 and 1992 and find that uninsured large deposits fell significantly relative to small insured deposits prior to failures. During the New England banking crisis, failing banks experienced a 70 percent decline in uninsured deposits in their final two years of operation while being able to raise insured deposits to replace the outflow. Billett, Garfinkel, and O'Neal (1998) also find that banks typically raised their use of insured deposits vis-a-vis wholesale deposits after being downgraded by Moody's.

*senior* claimants to the liquidated assets – in contrast to CK’s results.

The mechanism of these effects is that, absent a noisy public signal, uninformed wholesale financiers always roll over funding at the intermediate stage as banks are on average solvent (no news is good news). However, with the availability of a noisy public signal, wholesale financiers uninformed about bank-specific fundamentals can now choose to liquidate a bank based solely on a negative but possibly very noisy public signal.

The key inefficiency is that the incentives of wholesale financiers to liquidate based on noisy information can be too high compared to the socially optimal ones, particularly when they are *de facto* senior claimants on the liquidation value. Upon liquidation, senior wholesale financiers can obtain a larger share of a reduced bank asset pie, at the expense of providers of long-term funds such as passive core depositors. As a second-order effect, when wholesale financiers anticipate a high likelihood of an early liquidation with a safe exit, they become less interested in acquiring costly private information on bank project quality in the first place.

Therefore, in the presence of a noisy public signal, higher effective seniority of short-term wholesale funds has two effects. One, in line with CK, is the positive first-order effect that rewards monitoring and market discipline efforts. Another, a novel one, is the negative effect that increases the payoff to liquidating banks based on overly noisy information. The socially optimal seniority of short-term wholesale funds must therefore trade-off the two offsetting effects. We find that such welfare-maximizing seniority has an interior optimum. While the monitoring incentives of wholesale financiers increase in seniority for low values of seniority (the CK effect), they decrease for higher values of seniority when higher seniority translates purely into more liquidations. Deviations from that interior optimum to either side result in less monitoring and possibly more inefficient liquidations. This result contrasts with the CK benchmark in which higher seniority for the sophisticated funds is *always* better.

The precision of the noisy public signal (i.e., the probability that it is correct) is

one of the key parameters of the model. Its one interpretation is the availability of relevant public information on individual bank performance. This may vary across banks depending, for example, on asset type. That is, while the market prices of mortgage-backed securities (MBS) or house price changes can shed some light on the fundamentals of a typical mortgage bank that holds mainly arm's length assets (both MBS and residential mortgage loans), few similarly relevant public signals exist for traditional banks that hold mainly relationship-based small business loans. The signal precision can also be interpreted as the correlation between an individual bank's fundamentals with system-wide outcomes or indicators. With the proliferation of "risk transfer" and "risk dispersion" mechanisms, individual bank performances have become increasingly correlated, so that public signals now provide more relevant information on an individual bank's performance. Note, however, that these costless public signals can only provide *imperfect* information on an individual bank's true asset quality.

Our results reveal that the incentives for short-term wholesale financiers to liquidate strategically based on a noisy negative signal are *higher*, and therefore the welfare-maximizing seniority of wholesale funds (that compensates for excess liquidation incentives) is *lower*, when:

- *The noisy public signal is more precise*, yet not as precise as to make liquidation decisions based on it socially optimal;
- *The share of passive deposits in bank liabilities is higher*. Interestingly, the seemingly safe buffer of long-term funds provided by passive retail depositors in fact makes early liquidations less costly for wholesale financiers and discourages them from information acquisition efforts;
- *Liquidation value of bank assets is higher*. Liquidation value relates to a bank's cash holdings and the marketability of its long-term assets. By conventional wisdom, a higher liquidity buffer should better protect a bank against larger withdrawals. However, in our setup higher liquidation value has detrimental incentive effects as well: it lowers the cost of early liquidations for wholesale financiers and



increases the probability of inefficient "noisy" liquidations.

- *Interest rate offered to wholesale financiers in case of success is lower.* The interest rate offered to competitive wholesale financiers reflects the return on alternative use of money; it is lower for example in times of abundant liquidity supply. When the interest rate is lower, wholesale financiers have less to gain if a project succeeds in the long term. This encourages early liquidation.

In a bank cross-section, these predictions suggest that the use of senior short-term funds is beneficial in "traditional" banks that hold mainly opaque and nontradeable relationship loans, consistent with the "bright side" predictions of CK. Yet the "dark side" negative effects are likely to dominate in banks with large exposures to arm's length assets with readily available public information, particularly when short-term wholesale financiers are senior claimants.<sup>3</sup> However, importantly, private incentives would in fact drive arm's length banks towards actively using senior short-term wholesale funds: we show that interest rates demanded by wholesale financiers are lower when assets are marketable and public signals are available. Therefore, CK's insights best apply to the traditional relationship banking business with limited public information on asset quality, while our model sheds light on the new banking business characterized by arm's length transactions, high interbank correlations, and the availability of relevant public signals such as market prices and credit ratings.

To sum up, we show that higher seniority for wholesale funds is not *always* socially beneficial. In the presence of a costless but noisy signal on bank quality, higher seniority can in fact reduce monitoring and encourage inefficient liquidations. Social welfare is constrained-maximized for an intermediate level of seniority, depending on the bank's funding structure (i.e., share of passive retail deposits on the liability side), the precision of public signals on bank project quality (which often depends on the type of assets held), liquidation value of bank assets, and interest rates offered to wholesale financiers. This

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<sup>3</sup>Note that banks holding securitized assets (e.g. MBS) appear particularly vulnerable to the risk of premature liquidations: trading of assets provides a public signal on quality, and also raises their liquidated value.

is a novel result that usefully contrasts with CK and bears close resemblance to recent developments in the credit market, as well as some earlier instances of bank failures. It reveals the "dark" side of short-term wholesale funding, particularly when its providers are senior claimants.

The rest of the paper is structured as follows. Section 2 sets up the benchmark CK-type model of "bright side" of wholesale bank funding. Section 3 introduces the costless but noisy signal on bank project quality and models the "dark side" of wholesale bank funding. Section 4 provides a discussion of our results. Section 5 concludes.

## **2 The Bright Side of Wholesale Funding**

We start by outlining a version of the Calomiris and Kahn (1991) model. We use it to describe a benchmark "bright side" of bank wholesale funding. (We will use the same model with minor alterations in later sections to describe a "dark side" of wholesale funding.)

We demonstrate a number of key effects. First, the use of wholesale funds allows banks to expand the volume of lending beyond constraints of the fixed local depositor base. Second, wholesale financiers have the capacity to monitor banks and, if informed, exert welfare-enhancing market discipline: roll over funding to good banks but force liquidation of bad ones. Third, the monitoring incentives of wholesale financiers are maximized when they are senior creditors in early liquidations: this allows them to internalize the benefits of monitoring. Finally, and importantly, profit-maximizing private choices of banks and wholesale financiers are consistent with constrained-optimal outcomes: banks choose a maximum possible amount of wholesale funds and make them senior, to which wholesale financiers respond by monitoring and providing market discipline.

## 2.1 Model

Consider an economy with three dates: 0, 1, 2. The economy consists of a bank (with access to an investment project) and two types of bank financiers: retail and wholesale. Everyone is risk-neutral and there is no discounting.

**The project** A bank has exclusive access to a profitable but risky long-term project. For each unit invested at date 0, the project returns at date 2:  $X$  with probability  $p$  or 0 with probability  $1 - p$ . The project has a positive net present value:  $Xp > 1$ . The project may also be liquidated at date 1 returning  $L < 1$  per unit initially invested. The maximum investment size is 1.

**Funding** The bank has no initial capital and needs to borrow in order to invest. There are two types of financiers:

1. "*Retail depositors*" are unsophisticated and passive. They never get advance information on date 2 project realization, and never withdraw before date 2, providing a bank with a source of stable long-term funds despite being formally demandable. The passiveness of retail depositors is well-supported in the empirical literature; also see Shin (2008) for an analysis of the irony that retail deposits turned out to be the most stable source of funding for Northern Rock during the crisis. The interest rate payable on retail deposits (date 0 to date 2) is not risk-sensitive and is fixed at  $R_D$ :  $1 \leq R_D < pX$  (risk-sensitive deposit insurance is analyzed in Section 3.5). The key limitation of retail deposits is that they are scarce: the bank is endowed with a fixed deposit base of  $D < 1$ .

Using "retail deposits" as a metaphor for long-term funds, this model does not distinguish nondepository long-term funds such as equity, securitized notes, and covered bonds in the case of Northern Rock bank. The reason is that nondepository long-term funds share the same key properties as "retail deposits" in our model. First and most important, although more sophisticated, by contract they cannot

withdraw before date 2. Second, nondepository long-term funds are of limited supply as well. Third, the interest rate on long-term funds is fixed before the bank makes any other funding or investment decisions (e.g., the bank attracts long-term funds before date 0 when it is not able to commit to any future course of action). Therefore, long-term debts, wholesale or retail, in this model are analyzed under the same label of "retail deposits."

2. "*Wholesale financiers*" are sophisticated but *short-term*. They can monitor the bank at a cost. Monitoring may produce information on date 2 realization before date 1. Wholesale financiers can use that information in making roll-over decisions. Wholesale financiers are willing to lend to the bank any amount of funds at date 0 against real expected return  $\rho$ . Parameter  $\rho$  reflects the return on alternative use of wholesale financier's money, and can be interpreted as funding liquidity conditions. The bank's project is more valuable than alternatives, so that initial funding is always available:  $1 \leq \rho < pX$ .

The amount of wholesale funding attracted by the bank is denoted  $W$ . Since the maximum investment size is 1,  $W \leq 1 - D$ . Wholesale funding needs to be refinanced at date 1. If wholesale financiers refuse to roll over, the bank is forced into liquidation. The interest rate on wholesale funding is denoted  $R$ . We assume that  $R$  is set from date 0 to date 2. This allows the bank to avoid being hold up by wholesale financiers at date 1 (cf. von Thadden, 1995). The payoff to wholesale financiers in date 1 liquidations is determined by the liquidation value  $L(D + W)$  and their creditor seniority.

For simplicity, in the benchmark model, we consider a single but competitive wholesale financier to show that our results can be generated even in the absence of coordination failures. Section 4.3 discusses issues in the modelling of wholesale financiers and argues that a more detailed approach would make our key results only stronger.

**Monitoring** A wholesale financier can obtain information on the bank's date 2 project realization by monitoring the bank. Monitoring takes place in between dates 0 and 1. The financier chooses the intensity of monitoring  $m : 0 \leq m < 1$ . She incurs cost  $C(m)$  ( $C(0) = 0$ ,  $C(1) = \infty$ ,  $C'(0) = 0$ ,  $C''(m) > 0$ ). She then receives a *correct* signal of date 2 realization with probability  $m$ . That is, when monitoring succeeds, the financier obtains precise information of bank project quality. The financiers receive no signal at all with probability  $1 - m$ . In that case the financier knows that monitoring failed, and remains with information on prior probability of success  $p$  only.

**Seniority** The seniority of wholesale financiers relative to retail depositors in date 1 liquidations is described by the share  $s$  of liquidation value they receive ( $0 \leq s \leq 1$ ). In early liquidations, wholesale financiers receive  $sL(D + W)$  while retail depositors  $(1 - s)L(D + W)$ . Higher  $s$  represents a higher creditor seniority of wholesale financiers relative to retail depositors. Note that  $s$  describes the *effective* seniority of wholesale financiers. In practice, effective seniority is determined by a range of contractual choices: formal seniority, collateralization of funding, first-come-first-served rules, and official resolution options expected to be applied in case of bank failure.

**Continuation** For determinacy, we assume that at date 1 all agents marginally prefer a bank's continuation to liquidation when otherwise indifferent. Note that, since  $L < 1$ , bankers receive nothing in date 1 liquidations, and will therefore always prefer continuation. Retail depositors are set up as passive agents who always remain with the bank until date 2. Therefore, in this model, date 1 liquidations can only be triggered by short-term wholesale financiers.

Finally, we focus on the case when the amount of wholesale funding attracted by the bank is not too small compared to the liquidation value:

$$pW > L \tag{1}$$

This single assumption, while mildly restrictive, allows us to keep results easily

tractable. In particular, it assures that wholesale financiers are not repaid in full in date 1 liquidations:

$$WR > L(D + W)$$

Even more strongly, (1) implies that

$$pWR > L(D + W)$$

which rules out outcomes when uninformed senior wholesale financiers *always* prefer to liquidate the bank at date 1 to receive  $L(D + W)$  rather than wait until date 2 when they obtain expected  $pWR$ . This captures the stylized fact that "no news is good news" and absent negative information bank runs should be uncommon.

We analyze the "bright side" model in three steps. First, we consider the basic case of a bank funded by retail deposits only. Second, we introduce wholesale funds and show their positive effect on social welfare in a constrained optimum. Finally, we model the equilibrium resulting from private choices of banks and wholesale financiers, and show that its outcome is consistent with the maximization of social welfare.

## 2.2 Retail deposits only

Consider first a bank funded by retail deposits only. Then, its volume of initial investment  $D$  is lower than maximum possible 1. Maintaining spare investment capacity is inefficient, because the bank's project has a positive net present value.

Furthermore, the bank always continues until date 2. This is because bankers are at least indifferent when choosing between continuation and liquidation at date 1, while retail depositors are uninformed and passive. This means that bad projects are not terminated at date 1 (which would preserve liquidation value  $L$ ) but continue until date 2 returning 0. This is the second source of inefficiency.

Overall, the net present value of the bank's investment when financed with retail

deposits only is:

$$\Pi_{Dep} = D(pX - 1) \quad (2)$$

### 2.3 Wholesale funds: Welfare maximization

Now consider a bank that also attracts wholesale funds in the amount  $W$ . In this section, we derive the benchmarks for what would be the socially optimal monitoring and continuation decisions of wholesale financiers and the amount of wholesale funds attracted by a bank.

Consider first the continuation decision. At date 1, if monitoring was successful, a bad bank (which yields 0 at date 2) needs to be liquidated to preserve  $L$ . A good bank (which yields  $X$  at date 2) needs to be refinanced. When monitoring was unsuccessful, so the bank's project quality is unknown, a bank also needs to be refinanced since  $Xp > L$ .

Consider now the optimal intensity of monitoring,  $m^*$ , and the optimal amount of wholesale funds,  $W^*$ . The monetary value of social welfare:

$$\Pi = (D + W)(pX + m(1 - p)L - 1) - C(m) \quad (3)$$

is maximized for

$$W^* = 1 - D$$

so that a bank uses the maximum possible amount of wholesale funds and the complete initial investment opportunity of 1 is used, and for  $m^*$  given by

$$C'(m^*) = (1 - p)L \quad (4)$$

Comparing (3) with (2) highlights the beneficial effects of the use of wholesale funds: higher investment volume  $D + W$  instead of  $D$ , and preserving the liquidation value of some bad banks  $m^*(1 - p)L$  at the cost of monitoring  $C(m^*)$ .

## 2.4 Wholesale funds: Private equilibrium

We now derive equilibrium private choices of banks and wholesale financiers, and compare them with the socially optimal outcome.

**Wholesale financiers** Consider first the choices of wholesale financiers. They take decisions on the intensity of monitoring and on continuation (whether to roll over funds or liquidate the bank). Note immediately that their continuation decision is in line with the social optimum. If monitoring was successful, wholesale financiers have incentives to liquidate bad banks to receive  $sL(D + W)$ , and to roll over funding to good banks to receive  $WR$ . When monitoring was unsuccessful, uninformed wholesale financiers choose to roll over funding since, by (1),  $pWR > sL(D + W)$ .

Consider now the monitoring decision. In choosing the intensity of monitoring  $m$ , wholesale financiers maximize:

$$\Pi^W = pWR + m(1 - p)sL(D + W) - C(m)$$

which obtains their private choice of monitoring intensity  $m^W$  given by:

$$C'(m^W) = (1 - p)sL(D + W) \tag{5}$$

Observe from (4) and (5) that  $m^W = m^*$  for  $s = 1$  and  $D + W = 1$ . This means that wholesale financiers choose the optimal intensity of monitoring when they are senior creditors at the refinancing stage and the amount of wholesale funding is the maximum possible. The intuition for this outcome is that being senior allows wholesale financiers to fully internalize the benefits of monitoring: preserved liquidation value  $L(D + W)$  which is higher for a higher use of wholesale funds. Optimal high seniority of wholesale financiers is an important result as it describes the nature of optimal contracting arrangements between the bank and short-term wholesale financiers.



**Banks** The bank takes decisions on the amount of wholesale funds  $W$  to attract and on the creditor seniority  $s$  to offer them. The bank's surplus is:

$$\Pi^B = p [D(X - R_D) + W(X - R)] \quad (6)$$

The interest rate  $R$  demanded by competitive wholesale financiers, obtained from their zero-profit condition, is:

$$R = \frac{W\rho + C(m^W) - m^W(1-p)sL(D+W)}{Wp}$$

**Lemma 1**  $\Pi^B$  increases in  $s$  and  $W$ .

**Proof.** See Appendix. ■

The intuition for Lemma 1 is as follows.  $\Pi^B$  increases in  $s$  because  $R$  decreases in  $s$ : as wholesale financiers receive a larger share in early liquidations, the amount needed to compensate them in successful outcomes falls.  $\Pi^B$  increases in  $W$  because the bank is able to invest more funds, while at the same time the cost of monitoring per unit of wholesale funds used falls.

It follows directly from Lemma 1 that a bank acting in its own private interests will choose the maximum possible  $W = 1 - D = W^*$  and  $s = 1 = s^*$ , consistent with the socially optimal outcome. We can now formulate the main result of this section. It describes the benchmark "bright side" effects of bank wholesale funding.

**Proposition 1** *In the benchmark "bright side" case, the wholesale financiers' monitoring and continuation decision, and the banks' decisions on the amount of wholesale funds to use and their creditor seniority, are all in line with the constrained social optimum. In equilibrium, the amount of wholesale funds used by a bank is the maximum possible:  $W^* = 1 - D$ , wholesale funds are senior:  $s^* = 1$  so that all benefits of monitoring are internalized, and the investment of wholesale financiers in monitoring  $m^*$  is given by  $C'(m^*) = L(1 - p)$ .*

Observe that these predictions are fairly strong. Not only is the use of wholesale funding in banks unambiguously welfare improving, but also the private choices of banks and wholesale financiers fully coincide with welfare-maximizing outcomes.

### 3 The Dark Side of Wholesale Funding

We now turn to the analysis of the "dark side" of bank wholesale funding. Specifically, in this section we show how a plausible and minor change to the "bright side" CK-style setup of Section 2 can significantly alter its results.

To model the "dark side" of wholesale funding, we introduce an additional source of information available to "sophisticated" wholesale financiers. We assume that even when monitoring was unsuccessful (did not produce information about date 2 realization, either because of low investment in monitoring or merely by bad luck), wholesale financiers still obtain a free but *noisy* signal of date 2 realization in advance of date 1. That signal is best interpreted as a piece of publicly available information relevant to the bank's fundamentals but not perfectly so. Long-term debtors do not use this signal as (for contractual or behavioral reasons) they cannot change course on date 1 once invested on date 0.

We show that such a seemingly minor twist can lead to different outcomes (than in the CK model) for some banks. The presence of a costless but noisy signal lowers the incentives of wholesale financiers to monitor, and gives them excess incentives to liquidate banks based on overly noisy public information. These distortions are stronger when wholesale financiers are made senior claimants to the liquidated assets. The reason is that they are relatively protected in date 1 liquidations. After liquidation they are entitled to a larger share of the smaller liquidated value, at the expense of passive depositors. We show that, as a result, the incentives of opportunistic wholesale financiers are most aligned with the social optimum when they are assigned intermediate (rather than high) creditor seniority at the refinancing stage – different from the CK results.

We further address the incentives of banks. We show that, when banks (because of

limited liability) do not fully internalize the externalities on the providers of long-term funds (e.g., retail depositors) resulting from their contracting with short-term wholesale financiers, they may choose to assign too high seniority to short-term wholesale funds. This would lead to excess noisy liquidation in equilibrium, and bear close resemblance to effects observed during the recent turmoil. Moreover, comparative statics analysis shows that both the risk of noisy liquidation by wholesale financiers and the incentives of banks to borrow funds from them opportunistically – the "dark side" of wholesale funding – dominate in "modern" banks characterized by arm's length and tradable assets and an active combination of retail and wholesale funds in the liability structure.

### 3.1 Additional feature: A noisy public signal

To model the "dark side" of wholesale funding, we add a free but noisy signal on bank quality. The free signal is received by wholesale financiers after monitoring but before date 1. This sequence reflects the fact that the choice of intensity of monitoring is a strategic (anterior) decision and that monitoring needs to be performed continuously in the course of lending. Also observe that while monitoring is assumed to be precise if successful, the free signal is noisy: widely available public information is of lower quality than that produced through dedicated private investigation.

We specify the signal to have the same distribution of outcomes as that of the underlying project, but providing only noisy information on the final outcome. Formally, the signal takes two values: "positive" or "negative", and is characterized by a precision parameter  $\theta$  ( $0 \leq \theta \leq 1$ ;  $\theta = 0$  for uninformative;  $\theta = 1$  for precise). The probability of receiving a positive signal is  $p$  (same as for  $X$  at date 2); conditional on that the probability of getting  $X$  at date 2 is  $[p + \theta(1 - p)]$ , and that of getting 0 is  $[(1 - p) - \theta(1 - p)]$ . The probability of a negative signal is  $1 - p$  (same as for 0 at date 2); conditional on that the probability of getting  $X$  at date 2 is  $[p - \theta p]$ , and that of getting 0 is  $[(1 - p) + \theta p]$ .

The principal impact of the noisy signal on the mechanics of the model is as follows. Recall that without such a signal, uninformed wholesale financiers (who did not

receive precise information from monitoring) always rolled over funding at date 1. That was consistent with both welfare maximization ( $pX > L$ ) and their private incentives ( $pWR > sL(D + W)$ ). Now, however, uninformed wholesale financiers may choose not to roll over funding after receiving a negative but noisy signal. This paves the way for early liquidations of banks based only on free but noisy information ("noisy liquidations"). The focus of this section is to show how the possibility of early liquidations distorts incentives of both wholesale financiers and banks in such a way that their private choices may no longer lead to socially optimal outcomes.

We analyze the model in four steps. First, we derive the benchmark for the socially optimal use of the noisy costless signal. Second, we analyze the incentives of wholesale financiers. We show that they may have incentives for excess liquidations of banks based on overly noisy public information, particularly when they are senior. Third, we analyze socially optimal contracting with wholesale financiers. We show that, with the risk of jittery noisy liquidations, it is optimal that wholesale financiers be assigned intermediate (rather than high) creditor seniority. Finally, we study incentives of banks, and show how they can deviate from the socially optimal ones. Bank can opportunistically offer too high seniority to wholesale financiers to reduce the interest rates they have to pay on short-term wholesale funding. This is the reason why inefficient noisy liquidations can persist in equilibrium.

Throughout the section, we focus on cross-sectional predictions on the risk of early liquidations and inefficient bank funding choices. In the end of the section, we consider options for regulatory response.

### **3.2 Welfare maximization**

We start by outlining the benchmark socially optimal decisions on continuation, monitoring, and the use of wholesale funds in the presence of a free but noisy signal on bank project quality.

**Noisy liquidations** Consider the optimal use of a noisy public signal. When monitoring was successful, bank quality is known precisely. The noisy signal cannot add to the fundamental information produced through monitoring. As before, good banks need to be refinanced while bad banks need to be liquidated.

When monitoring was unsuccessful, without the noisy signal, continuation was always optimal at date 1. The noisy signal refines date 1 probabilities of success or failure at date 2. For a positive noisy signal, the posterior of success at date 2 increases to  $p + \theta(1 - p)$ . It remains optimal that the bank is refinanced. However, for a negative noisy signal, the posterior of success at date 2 falls to  $[p - \theta p]$ . There are two possible outcomes. If the precision  $\theta$  of the noisy signal is low so that  $[p - \theta p]pX \geq L$ , it is still optimal to refinance the bank (as was in the case of no information). In this case the noisy signal is effectively disregarded: it has no impact on the continuation and by implication on any other decisions. However, if the precision of the noisy signal  $\theta$  is high enough so that  $[p - \theta p]pX < L$ , it is optimal to liquidate the bank based *solely* on a noisy signal. The threshold value of  $\theta$  is

$$\theta^* = 1 - \frac{L}{p^2 X} \quad (7)$$

Note that, unless  $\theta = 1$ , some good banks will suffer noisy liquidations as well.

**Monitoring and use of wholesale funds** Now consider how the availability of a costless noisy signal affects the optimal intensity of monitoring and the optimal amount of wholesale funds to use. The impact depends on the precision of a noisy signal. Recall that, when its precision is low,  $\theta \leq \theta^*$ , it is optimal to disregard the noisy signal. As a consequence, the maximization problem is the same as in the benchmark case (3). The optimal amount of wholesale funds to use is the maximum possible  $W^* = 1 - D$  and the optimal amount of monitoring is  $m^*$  as defined by (4).

When the precision of the noisy signal is high,  $\theta > \theta^*$ , it is socially optimal to use the noisy signal, and liquidate the bank when it is negative. The monetary value of

social welfare in this case is:

$$\Pi_{Liq} = (D + W) (m [pX + (1 - p)L] + (1 - m) [p [p + \theta(1 - p)] X + (1 - p)L] - 1) - C(m) \quad (8)$$

The term  $m [pX + (1 - p)L]$  is the payoff to successful monitoring, similar to (3). The term  $(1 - m) [p [p + \theta(1 - p)] X + (1 - p)L]$  is novel: it is the payoff from using the noisy signal when monitoring was unsuccessful (and liquidating the bank upon a negative signal). The probability of a positive signal is  $p$ ; conditional on it the bank is refinanced and yields  $X$  with probability  $[p + \theta(1 - p)]$ . The probability of a negative signal is  $(1 - p)$ ; the bank is liquidated to preserve  $L$ .

As before, the social welfare (8) is increasing  $W$ , so that it is optimal to use as much wholesale funding as possible:  $W_{Liq}^* = 1 - D = W^*$ . The optimal intensity of monitoring  $m_{Liq}^*$  is given by:

$$C'(m_{Liq}^*) = p(1 - p)(1 - \theta)X \quad (9)$$

Observe that  $m_{Liq}^* < m^*$ . This is easy to verify by applying the condition for using the noisy signal  $[p - \theta p]pX < L$  to (4) and (9). The intuition is that the availability of a noisy but free signal makes the information obtained through costly monitoring less valuable.

### 3.3 Wholesale financiers: Private incentives and socially optimal seniority

Now consider private choices of wholesale financiers.

**Noisy liquidations** When monitoring was successful, as before, wholesale financiers had incentives to follow its outcome: refinance known good banks and force liquidation of bad ones. When monitoring was unsuccessful, uninformed wholesale financiers can use the noisy public signal. Upon a negative noisy signal, their expected continuation payoff is  $[p - \theta p]WR$ . Their liquidation payoff is  $sL(D + W)$ . For wholesale financiers,

it is privately optimal to follow a noisy signal and liquidate the bank for

$$sL(D + W) > [1 - \theta]pWR \quad (10)$$

Expression (10) can be interpreted either as sufficiently high precision of the noisy signal:

$$\theta > \theta^W = 1 - \frac{sL(D + W)}{pWR} \quad (11)$$

or as sufficiently high seniority of wholesale financiers:

$$s > s^W = \frac{(1 - \theta)pWR}{L(D + W)} \quad (12)$$

Note that the private threshold  $\theta^W$  can be either above or below the socially optimal threshold  $\theta^*$  depending on the value of  $s$ . When  $s$  is low and  $\theta^W > \theta^*$ , wholesale financiers have insufficient private incentives to liquidate banks. When  $s$  is high and  $\theta^W < \theta^*$ , wholesale financiers have excess private incentives to liquidate banks based solely on noisy information. However, observe that wholesale financiers always have excess incentives to liquidate banks based on noisy information when they are senior ( $s$  is close to 1):  $\theta_{s=1}^W < \theta^*$ .

From this point on, we will focus on the case with the richest interpretations. We consider the case when private and public incentives to liquidate banks based on noisy information diverge. Specifically, we consider  $\theta$  in the interval  $\theta_{s=1}^W < \theta < \theta^*$ . This describes the environment where the noisy public signal is not very informative, so that from the social welfare perspective it is optimal to disregard it. However, the signal is still informative enough to be used by senior wholesale financiers, and to trigger "noisy" bank liquidations.

**Monitoring** Consider now the monitoring choices of wholesale financiers. Recall that when wholesale financiers are sufficiently junior,  $s \leq s^W$ , they disregard the noisy signal. Therefore, their private choice of monitoring intensity is the same as the benchmark  $m^W$

(5).

However, when wholesale financiers are sufficiently senior,  $s > s^W$ , they have incentives to use the noisy public signal and liquidate the bank when it is negative. Then, in choosing monitoring intensity, they maximize

$$\Pi^W = m[pWR + (1-p)sL(D+W)] + (1-m)[p[p + \theta(1-p)]WR + (1-p)sL(D+W)] - C(m) \quad (13)$$

which obtains:

$$C'(m_{Liq}^W) = p(1-p)(1-\theta)WR_{Liq} \quad (14)$$

Observe that, unlike in expression for  $m^W$  (5),  $s$  does not enter directly into the specification of  $m_{Liq}^W$  (14). Rather, it affects  $m_{Liq}^W$  indirectly through  $R_{Liq}$ . To see that in detail, consider the interest rate charged by competitive financiers:

$$R_{Liq} = \frac{W\rho + C(m_{Liq}^W) - (1-p)sL(D+W)}{m_{Liq}^W Wp + (1-m_{Liq}^W)[p + \theta(1-p)]Wp}$$

As  $s$  increases and wholesale financiers receive more in date 1 liquidations, they require less compensation in case of date 2 success: in equilibrium,  $R_{Liq}$  decreases in  $s$ . Therefore, since  $m_{Liq}^W$  increases in  $R_{Liq}$ , it decreases in  $s$ . This contrasts with the benchmark case without the noisy signal where  $m^W$  (5) increased in  $s$ . The intuition behind this result is that senior wholesale financiers who can use noisy signals become less interested in the bank's long-term value. Indeed, they can easily liquidate the bank on mild negative news before the long-term value is realized, at only very low private cost.

This makes  $s = s^W$  a threshold point not only for the liquidation decision, but also for the choice of intensity of monitoring of wholesale financiers. The properties of  $s^W$  are summarized in the following lemma:

**Lemma 2** *Consider  $s^W$  given by (10).*

1. *For  $s \leq s^W$  wholesale financiers never liquidate a bank based on noisy information and the intensity of their monitoring increases in seniority:  $\partial m^W / \partial s > 0$ , consistent*



with the benchmark "bright side" of bank wholesale funding.

2. For  $s > s^W$  uninformed wholesale financiers choose to liquidate a bank following a negative noisy signal and the intensity of their monitoring decreases in seniority:  $\partial m_{Liq}^W / \partial s < 0$ , contrasting with the "bright side" benchmark.

3. The intensity of monitoring chosen by wholesale financiers is maximized for  $s = s^W$ , that is, for an intermediate value of their seniority.

**Proof.** See Appendix. ■

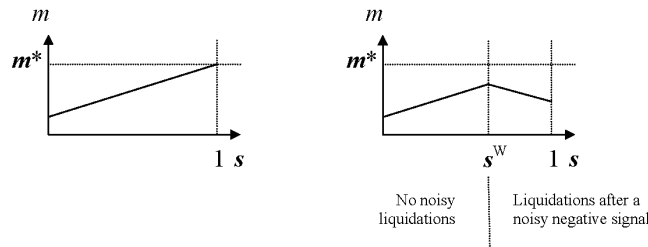
The contrasting effects of seniority on the behavior of wholesale financiers with and without the noisy public signal are illustrated in Figure 1. The left panel shows that, in the benchmark case without a noisy public signal, the monitoring effort of wholesale financiers increases monotonically in their creditor seniority. The right panel depicts the same relation, but with the noisy signal. There, for low values of seniority, wholesale financiers disregard the noisy signal so their actions are identical to those in the benchmark case. However, when seniority exceeds the threshold value  $s = s^W$ , wholesale financiers start (a) to liquidate based on a negative noisy signal, and (b) to reduce monitoring efforts in response to higher seniority.

**Figure 1.**

**Liquidation and monitoring decisions of wholesale financiers.**

*Left panel: Without a noisy signal*

*Right panel: With a noisy signal*



**Optimal use and seniority of wholesale funds** We now take the incentives of wholesale financiers identified in Lemma 2 as given, and ask what would be the resulting *socially optimal* use  $W$  and seniority  $s$  of wholesale funds. Of course, in practice the decisions of how much wholesale funds to use and which creditor seniority to offer them are taken by a bank with the objective of maximizing its private surplus. We will consider bank's incentives immediately afterwards. However, understanding the socially optimal use of wholesale funds would allow us to see whether the private choices of banks are consistent with social welfare maximization, and if not, identify scope for regulatory intervention.

The key result on the optimal use of wholesale funds by banks is as follows:

**Proposition 2** *Consider the case with possible welfare-reducing noisy liquidations,  $\theta_{s=1}^W < \theta \leq \theta^*$ . Then the socially optimal creditor seniority of wholesale financiers is  $s = s^W$  (12). This is the intermediate level of seniority, lower than the "bright side" benchmark  $s = 1$ . Setting  $s = s^W$  fully aligns the continuation decision of wholesale financiers with the socially optimal: there are no noisy liquidations. At the same time,  $s = s^W$  maximizes the intensity of monitoring privately chosen by wholesale financiers, albeit at the level below the social optimum:  $m^W(s^W) < m^*$ . The optimal amount of wholesale funds remains the highest possible  $W = 1 - D = W^*$ .*

Point  $s^W$  can be thought of as the highest seniority of short-term wholesale funds that does not give rise to early liquidations. For  $s < s^W$  higher seniority increases the intensity of monitoring chosen by wholesale financiers. After that, for  $s > s^W$ , fundamentally uninformed wholesale financiers will start liquidating banks based on a negative noisy signal. That is not socially optimal. Moreover, for  $s > s^W$ , the monitoring effort of wholesale financiers starts to decrease in higher seniority. In effect, for  $s > s^W$ , higher seniority of wholesale financiers translates not into increased intensity of monitoring (as was in the "bright side" case) but purely into excess liquidations – and less monitoring.

The fact that intermediate rather than high seniority of wholesale funds is optimal

in order to prevent excess liquidations of banks based on overly noisy public information is a key departure from the CK-type result describing the "bright side" of wholesale bank funding.

### 3.4 Comparative statics

Lemma 2 and Proposition 2 offer interesting cross-sectional predictions on (a) the risk of excessive noisy liquidations in different types of banks, and (b) the socially optimal seniority of short-term wholesale funds in different types of banks. Note that (a) and (b) are just two sides of the same coin: certain bank characteristics that predict a higher risk of excessive noisy liquidations also prescribe as socially optimal an assignment of lower seniority to wholesale funds. This would increase the losses that wholesale financiers incur in early liquidations, and thus reduce their incentives to liquidate based on overly noisy information.

Consider inequalities (10) and (12). It is more likely that they are satisfied, so that the risk of noisy liquidations by short-term wholesale financiers is higher, when:

- $\theta$ , the "precision" of the public noisy signal on bank project quality, is higher (but not perfect). Note that in plain language versus theorist language,  $\theta$  is better interpreted as the "relevance" of the noisy signal to bank project quality.
- The bank's liquidation value  $L$  is higher.

Also, from (10), the risk of noisy liquidations is higher when  $s$ , the actual seniority of short-term wholesale funds, is higher. However, this parameter does not vary much across banks and is less interesting in our comparative statics analysis.

The above two predictions suggest an interesting distinction between (1) "traditional" banks holding relatively relationship-based small business loans (which are associated with low  $\theta$  and  $L$ ) and (2) "modern" banks holding mostly tradable arm's-length assets (which are associated with relatively higher liquidation value  $L$ , and relatively

more relevant public information on quality – high  $\theta$  – because of the availability of secondary market prices and credit ratings).

In both types of banks, the "bright side" benefit as modeled by CK is at work: higher seniority to wholesale funds encourages them to monitor. However, the "dark side" cost that works in the opposite direction is likely to be greater for "modern" banks. In "traditional" banks characterised by low  $\theta$  and  $L$ , according to the comparative statics predictions above, the "dark side" of wholesale funding has a relatively small impact and is likely dominated by the "bright side" benefits. In this case, the CK model provides a good approximation of reality. In "modern" banks, however, because of high  $\theta$  and  $L$ , the risk of liquidations based on noisy public information is higher and can offset and sometimes outweigh the "bright side" benefit. In this case, the "dark side" effect cannot be neglected.

The results may also have interesting implications for credit cycles. Suppose  $\theta$ , the relevance of a noisy public signal (e.g., the general performance of the banking sector), is higher during recessions and lower during expansions, i.e., only bad banks fail in expansions but all banks are affected in recessions (a la Rajan 1994). Then the liquidity risk we model should be higher during recessions because macroeconomic news matter more. However, there is not much consensus on the procyclicality or countercyclicality of performance difference between good and bad banks, and therefore our prediction on the countercyclicality of liquidity risk remains speculative.

Finally, comparative statics can also show that the risk of noisy liquidations by short-term wholesale funds is higher when:

- $\rho$ , the opportunity cost of wholesale funds (which affects the interest rate  $R$ ) is lower. Periods of abundant liquidity are typically characterized by low cost of wholesale funds  $\rho$ .
- Wholesale funds  $W$  is low relative to retail deposits  $D$ . Note that "retail deposit" should be broadly interpreted as any type of long-term funding. In the case of Northern Rock, besides 27 percents of customer deposits,  $D$  would also include

contractually long-term securities such as equity, securitized notes, and covered bonds, which accounted for another 50 percents of the bank's liabilities. Contrary to media perceptions, in Northern Rock short-term funding  $W$  was not very high relative to long-term funding  $D$ . This prediction suggests, interestingly, that long-term funds  $D$ , while being a seemingly safe liability by themselves, also serve as an exit buffer for short-term wholesale financiers and make liquidations less costly for them, increasing the risk of overly noisy liquidations and reducing the wholesale financier's monitoring incentives.

### 3.5 Banks' incentives to use wholesale funds

The previous section has established socially optimal seniority for opportunistic wholesale financiers: how their choices can be brought closer to the social optimum by assigning them an intermediate level of creditor seniority  $s^W$ . However, in practice the decisions on how much wholesale funds to use and on which creditor seniority to offer them are taken by a bank with the objective of maximizing its private surplus. In this section, we will study the incentives of banks, and ask whether unconstrained bank choices can deviate from the social optimum.

The key mechanism behind the results of this section is that banks do not internalize the externalities of their contracting with short-term wholesale financiers on passive depositors (and other providers of long-term funds). The reason is that the interest rate on deposits and long-term funds is fixed in advance: a higher risk of nonrepayment does not translate into a correspondingly higher interest rate punishment for a bank. This leads to a sort of "risk-shifting" behavior on the part of banks: banks with existing leverage have incentives to attract overly risky secondary sources of funding (cf. Myers and Majluf, 1984). To sum up, the reason for the externality is that deposits and other long-term funds are generally not fully efficiently priced.

**Bank's choice of seniority for wholesale financiers** Consider the impact of offering wholesale financiers a higher creditor seniority than is socially optimal:  $s > s^W$ .

Recall that the social cost of this action is (a) inefficient noisy liquidations and (b) lower intensity of monitoring by wholesale financiers. Let us now consider private costs and benefits for the bank. The bank's private cost is similar to the social one: a bank loses when good projects are liquidated prematurely in early liquidation. However the bank also has a private benefit. Offering higher seniority to wholesale financiers reduces the interest rate  $R$  charged by them. As long as the interest rate charged by providers of long-term funds (e.g., passive depositors)  $R_D$  is fixed, this leads to an increase in a bank's surplus. When the net effect of higher seniority on a bank's surplus is positive (the lower interest rate effect dominates the higher risk of liquidation effect), the bank has private incentives to offer too high seniority to short-term wholesale financiers.

To see this formally, compare the bank's surplus from selecting  $s = s^W$  versus some  $s > s^W$ .

For  $s = s^W$  we have:

$$\Pi_{s=s^W}^B = p [D(X - R_D) + W(X - R)] \quad (15)$$

where

$$\begin{aligned} R &= \frac{W\rho + C(m^W) - m^W(1-p)sL(D+W)}{Wp} \\ s &= s^W \end{aligned}$$

For  $s > s^W$  we have<sup>4</sup>:

$$\Pi_{Liq}^B = [p - (1 - m_{Liq}^W)p(1 - \theta)(1 - p)] [D(X - R_D) + W(X - R_{Liq})] \quad (16)$$

---

<sup>4</sup>Note that  $m^W$  and  $R$  are continuous at  $s^W$ :  $m^W(s^W) = m_{Liq}^W(s^W)$  and  $R(s^W) = R_{Liq}(s^W)$ . This is easy to show formally by substituting expressions for  $m^W$  (5),  $s^W$  (12), and  $m_{Liq}^W$  (14). The intuition is that, although at  $s^W$  there is a discrete change in the liquidation strategy of wholesale financiers (from not using to using the noisy signal), at  $s^W$  they are indifferent between the two. Therefore, marginal changes in  $s$  lead to marginal changes in  $m$  and  $R$ .

where

$$R_{Liq} = \frac{W\rho + C(m_{Liq}^W) - (1-p)sL(D+W)}{W(p - (1 - m_{Liq}^W)p(1-\theta)(1-p))}$$

Compare  $\Pi_{s=s^W}^B$  and  $\Pi_{Liq}^B$ . Observe that  $\Pi_{Liq}^B$  incorporates a lower probability of a bank's success: it is reduced by the probability of inefficient liquidations  $(1 - m^W)p(1 - \theta)(1 - p)$ . As a result there is a discrete fall in  $\Pi^B$  as soon as  $s$  exceeds  $s^W$  as a bank becomes subject to inefficient early liquidations. The value of that fall is

$$\Delta = (1 - m^W)p(1 - \theta)(1 - p) [D(X - R_D) + W(X - R)] \quad (17)$$

However, after the immediate fall at  $s^W$ ,  $\Pi_{s>s^W}^B$  can start increasing in  $s$ . The reason is that a higher  $s$  gives wholesale financiers more in date 1 liquidations (at no expense to the bank), and allows the bank to repay them less in case of success at date 2. To see this formally, consider

$$\frac{d\Pi_{Liq}^B}{ds} = -\frac{dR_{Liq}}{ds} [p - (1 - m_{Liq}^W)p(1 - \theta)(1 - p)] W + \frac{dm_{Liq}^W}{ds} p(1 - \theta)(1 - p) [D(X - R_D) + W(X - R_{Liq})] \quad (18)$$

The first term on the right-hand side is overall positive: it reflects the reduction in the interest rate that the bank has to pay on short-term wholesale funds:  $dR_{Liq}/ds < 0$ . The second term on the right-hand side is overall negative:  $dm_{Liq}^W/ds < 0$  as with higher  $s$  wholesale financiers lose their incentives to monitor the bank, leading to more ineffective liquidations.

Either effect can dominate another depending on parameter values. For example, one can verify that for a very low  $L$  the term  $dR_{Liq}/ds$  is so low that the second term dominates and  $d\Pi_{Liq}^B/ds$  is negative. Then the bank would never have incentives to choose  $s > s^W$ . Yet, as another example, when the impact of  $s$  on  $m_{Liq}^W$  is very small, the second term is so low that the first term dominates and  $d\Pi_{Liq}^B/ds$  is positive. In this case, should the initial fall in a bank's surplus  $\Delta$  be outweighed by a subsequent increase of  $\Pi_{Liq}^B$  as  $s$  becomes high enough, the bank would have incentives to assign

wholesale financiers a higher seniority  $\hat{s} > s^W$  than is socially optimal.

It is this latter case that corresponds to the *dark side* of wholesale bank funding. There, banks opportunistically assign very high seniority to wholesale financiers in order to benefit from savings on interest rate payments that they have to make in case of success. Senior wholesale financiers, in turn, opportunistically liquidate banks based on very noisy public information, although that is not socially optimal. We now focus on this case in more detail.

**"Dark side" in equilibrium** We first prove the existence of the "dark side" case when banks have incentives to assign short-term wholesale financiers a higher creditor seniority than is socially optimal.

**Proposition 3** *There exist parameter values of  $\theta$ ,  $L$ ,  $D$ ,  $W$  and  $\rho$  such that for some  $\hat{s} > s^W$ :  $\Pi_{Li}^B(\hat{s}) > \Pi_{s=s^W}^B$  so that a bank has incentives to assign higher creditor seniority to wholesale financiers than is socially optimal.*

**Proof.** See Appendix. ■

Proposition 3 is the key result of this paper. It proves the existence of the "dark side" of wholesale funding. It demonstrates the existence of outcomes where banks opportunistically assign too high seniority to wholesale financiers, while wholesale financiers opportunistically liquidate banks based on too noisy public information can exist in equilibrium.

We now turn to comparative statics. In order to formulate tractable results, we require an additional simplification. We focus on the case when  $m_{Li}$  is relatively unaffected by changes in exogenous parameters that we are going to vary. This is the case, for example, when  $C(m)$  is relatively flat. Otherwise minor changes in exogenous parameters could lead to significant changes in  $m_{Li}$  (e.g., it may suddenly turn into zero) which would significantly complicate the analysis.

Under this condition, interest rate saving effects likely dominate higher probability of bank failure effects in  $d\Pi_{Li}^B/ds$ , and therefore on the net increase bank's incentives



to choose  $s > s^W$  over  $s^W$  when:

- The precision of a noisy signal on bank project quality  $\theta$  is higher (but not perfect).  
The intuition is that a higher  $\theta$  makes the liquidation decisions more precise (but again not perfect) and therefore less costly: it is easy to see in (17) that a higher  $\theta$  reduces  $\Delta$ . One can also observe in (18) that a higher  $\theta$  increases a multiplier of  $dR_{Liq}/ds$ , leading to a higher  $d\Pi_{Liq}^B/ds$ .
- The bank's liquidation value  $L$  is higher. To verify this observe first that  $L$  does not affect  $\Delta$ . The reason is that although  $L$  enters expressions for  $R$  and  $m^W$  it does so always proportionally to  $s^W$ . Yet  $s^W$  itself is inversely proportional to  $L$  (as seen in (12)). Therefore  $d\Delta/dL = 0$ . At the same time a higher  $L$  increases the value of  $dR_{Liq}/ds$  leading to a higher  $d\Pi_{Liq}^B/ds$ .

Observe that these predictions are reinforcing the comparative statics observed in the incentives of providers of wholesale funds. Precisely the same characteristics of "modern" rather than "traditional" banking – more relevant public signals on project quality and a higher liquidation value – increase the risk of "noisy" liquidations by wholesale financiers *and* make banks more likely to assign the providers of wholesale funds with inefficiently high creditor seniority.

We will not formulate results for the impact of funding structure ( $D$  and  $W$ ) on banks' incentives. The reason is that those are ambiguous. Higher  $D$  and  $W$  increase both losses due to noisy liquidations  $\Delta$  and interest rate savings  $dR_{Liq}/ds$ . Depending on parameter values, either effect can dominate.

To close the solution, we verify that the bank always chooses to use the maximum amount of wholesale funds  $W = 1 - D = W^*$ . Lemma 1 proved that  $\Pi^B$  increases in  $W$  for  $s \leq s^W$ . It is straightforward to obtain through similar derivations that  $\Pi_{Liq}^B$  also increases in  $W$  (there is an additional effect that as  $m_{Liq}^W$  falls in  $W$  the probability of noisy liquidations falls, increasing  $\Pi_{Liq}^B$ ). The intuition, as before, is that using a higher amount of wholesale funds allows banks to utilize more of the valuable investment opportunity and to reduce the per-unit cost of monitoring.

### 3.6 Policy response

Our model has identified potential inefficiencies in the banks' use of wholesale funds:

- Wholesale financiers can liquidate banks based on overly noisy public signals;
- Banks can assign too high seniority to wholesale financiers, creating greater risk of early liquidations.

Here we analyze actions that regulators can take to bring the choices of banks and wholesale financiers closer to the social optimum. While regulators have little leverage over the actions of wholesale financiers, they can try and influence banks' choices. Their objective is to make sure that the banks do not assign wholesale financiers seniority higher than  $s = s^W$  as defined by (12). Below we describe some tools at their disposal.

**Imposing lower seniority for short-term wholesale financiers** If regulators could directly dictate effective seniority for short-term wholesale financiers, they could simply impose  $s = s^W$ . Yet there are a number of reasons why this may be difficult or impossible. First, optimal seniority  $s^W$  varies across banks and over time as bank characteristics change. Second, as  $s$  is defined as *effective* seniority and not just formal seniority, statutory requirements can be irrelevant. Finally, a high  $s$  is implied by the first-come-first-served withdrawal rule: historically most wholesale funds managed to exit before retail depositors started to form lines.

**Taxing the use of short-term wholesale funds** Recall that the private incentives of banks are not in line with the socially optimal because banks do not internalize the negative effects (on depositors and other providers of long-term funds) of the use of risky senior short-term wholesale funding. The interest rate  $R_D$  is risk-insensitive due to the protection by deposit insurance, or in any case is set before short-term funds are attracted. Moreover a bank is typically unable to commit in advance to any future course of actions relating to its future funding choices. As our model shows, by offering

a higher  $s$  to wholesale financiers, the bank is able to save on its total interest rate payments by paying a lower interest rate to wholesale financiers.

Authorities can attempt to restore a bank's incentives to social optimal by charging the bank (through taxes or deposit insurance premia) for whatever private benefits it obtains through offering a too high  $s$  to wholesale financiers. The problem, again, is how to define "too high" an  $s$ . Recall that the threshold value  $s^W$  for "too high" is different for different banks. We first analyze a possible taxation structure that does not rely on knowing the precise  $s^W$  for each bank, identify its shortcomings, and then propose a taxation structure that requires knowing  $s^W$  (which is thus more difficult to implement).

Consider  $\Pi_{Liq}^B$ : the bank's profit function at  $s > s^W$  (16). Again assume for simplicity that the effects of wholesale financiers' monitoring choices are secondary:  $m$  is fixed. Interest rate savings from a given  $s$  are  $(1-p)sL(D+W)$ . To remove them from the profit function the bank can be taxed or charged with a deposit insurance premium of

$$T = (1-p)sL(D+W) \quad (19)$$

It is easy to observe that  $d(\Pi_{Liq}^B - T)/ds < 0$ . The intuition is that the interest rate savings effect is now offset by tax  $T$  on the opposite direction. Under such a tax, a bank has no incentive to choose  $s > s^W$ .

However, under tax  $T$  that does not rely on knowing  $s^W$  the bank has no incentive to choose  $s^W$  either. Consider  $\Pi^B$ : the bank's profit for  $s < s^W$  (6). There, interest rate savings from a given  $s$  are  $m(1-p)sL(D+W)$ , and one can verify that  $d(\Pi^B - T)/ds < 0$ . Under a tax  $T$  (19) a bank simply has no incentives to choose any  $s > 0$  because the tax penalizes the use of senior wholesale funds in general, even when the seniority assigned to wholesale funds is lower than  $s^W$ .<sup>5</sup>

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<sup>5</sup>Interestingly, the tax  $T$  although blunt can be welfare improving under some conditions. To see that, consider the case when the level of monitoring is almost fixed. Then the key to achieving high social welfare is to avoid ineffective liquidations. The tax  $T$  does just that. More generally, observe that the tax  $T$  reduces monitoring incentives compared to the socially optimal level but improves liquidation incentives. When it is more important to avoid inefficient liquidations rather than to incentivize monitoring, tax  $T$  improves social welfare.

To address this problem, authorities could try to relate taxes or insurance premia to  $s^W$ . Certainly, their ability to implement such taxes depends on knowing  $s^W$  for each individual bank. The revised insurance premia formula

$$\hat{T} = (1 - p) \max\{(s - s^W); 0\} L(D + W)$$

would counterbalance banks' incentives to choose  $s > s^W$  but would not affect banks' choices on  $s \leq s^W$ , therefore leading to a socially optimal outcome  $s = s^W$ . This formula imposes higher information requirements on the authorities. Besides higher premia for more risky banks (higher  $1 - p$ ), it prescribes a number of other bank characteristics that the authorities should target.

First, the formula suggests that banks assigning higher *effective* seniority  $s$  to wholesale funds should pay a higher deposit insurance premium. In practice, it is hard to quantify  $s$ . However, it is fair to say that under a first-come-first-served withdrawal rule wholesale funds with shorter remaining maturity enjoy relatively higher effective seniority than those with longer remaining maturity.

Second, it is important to identify a bank's optimal seniority  $s^W$ , which varies across banks dependent on a number of parameters reflecting bank characteristics. We can compute the optimal seniority  $s^W$  in our theoretic model because the model is very stylized. In practice, the authorities can also rely on a small number of key bank characteristics to approximate  $s^W$ . For example, our model predicts that banks holding arm's length assets are associated with a lower  $s^W$  than banks holding mainly relationship-based small business loans, because the former are typically associated with higher  $L$  and  $\theta$ . Therefore, a bank with a high percentage of small business loans may be exempted from such an insurance premium surcharge imposed on high arm's length asset banks.

Third, this optimal deposit insurance premium formula suggests that the premium be assessed in proportion to the bank's total liabilities  $D + W$  rather than only insured retail  $D$ . The reason is that the externalities imposed by the use of short-term wholesale funds – which risk-based deposit insurance attempts to correct – are proportional to the

total value of liabilities.<sup>6</sup>

Finally, the formula also suggests charging higher premia for banks with more liquid balance sheets (i.e., higher  $L$ ). This might sound counter-intuitive at first sight, because, in models that feature coordination failures (e.g., Diamond and Dybvig, 1983), a more liquid balance sheet may reduce the probability of bank runs. However, the reality is that wholesale funds usually manage to run down a bank's liquid assets ahead of retail depositors, and therefore the benefits of a liquid balance sheet accrue mainly to the short-term wholesale financiers and not to the retail depositors or the deposit insurance agency. Indeed, as reflected in our model, short-term financiers charge lower interest rates for funding banks with a more liquid balance sheet, and banks use such funds because of the lower interest costs. We are not the first to uncover a "paradox of liquidity." Myers and Rajan (1998) show that greater asset liquidity reduces the management's ability to commit credibly to an investment strategy that protects investors. In our case, greater asset liquidity, by allowing the wholesale financiers to exit without much loss, reduces their incentive to adopt liquidation strategies that protect retail depositors.

**Outright ban on the use of short-term wholesale funds** Another option is to restrict the use of wholesale funds in certain banks.

**Lemma 3** *There exist parameter values of  $\theta$ ,  $L$ ,  $D$ ,  $W$  and  $\rho$  such that social welfare under  $W = 0$  is higher than  $W = 1 - D$  when banks are opportunistic.*

**Proof.** See Appendix. ■

Lemma 3 shows that there exist parameter values such that an outright ban on the banks' use of wholesale funds is better than exposing the system to the risk of noisy

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<sup>6</sup>Interestingly, this corresponds to the current FDIC policy that assesses deposit insurance premia based on a bank's "total deposits" (i.e., not only insured deposits but also uninsured ones that behave like wholesale funds, such as jumbo CDs). The stated reason for this FDIC policy is that it is technically difficult to separate insured and uninsured deposit accounts. Our model offers a deeper economic explanation: such a policy reduces banks' incentive to attract risky short-term wholesale funds such as jumbo CDs. Our model further suggest that the FDIC can do even better by including in the assessment base all other short-term liabilities, such as commercial paper and interbank borrowings, as well as possibly long-term liabilities.

liquidations. The intuition is that the cost of not using wholesale funds is unused investment opportunities and no monitoring. Yet when unused investment opportunities are not too high and when wholesale financiers provide little monitoring (which is plausible when they are too senior and hence by Lemma 2 have lower incentives to monitor), an outright ban on the use of wholesale funding in banks can improve social welfare.

Note that unused investment opportunities are not too high when  $D$  is high. As we showed in comparative statics in Section 3.3, these are precisely the values where wholesale financiers' are likely not to monitor banks. So for such *depository* banks it will most likely be socially optimal to restrict their use of wholesale funds. On the use of wholesale funds, Acharya, Gale, and Yorulmazer (2008) also provide a model to explain why markets for rollover debt may experience sudden freezes and also suggest a regulatory restriction against excessive reliance on rollover finance. However, our model prescribes such a restriction only for some banks meeting the conditions described above, and that the ban may not be optimal for others.

## 4 Discussion

### 4.1 Relationship to corporate finance literature

The tension between the lenders' incentives to monitor and the risk of inefficient early liquidations, associated with the use of short-term debt, has been well explored in the corporate finance literature. Sharpe (1991), Diamond (1992), and Titman (1992) consider settings in which short-term lenders can refuse to roll over funding in the case of bad news at the intermediate stage of a project's realization, creating the risk of inefficient liquidations. The incentives to liquidate prematurely can increase further when the lender enjoys an informational monopoly at the refinancing stage (Rajan, 1992). Berglof and von Thadden (1994) show how incentives of short-term financiers to monitor and liquidate can be balanced by offering short-term lenders an optimal senior claim that

gives them a higher liquidation payoff at the expense of long-term creditors.<sup>7</sup>

While in the corporate finance literature, banks are typically considered as lenders to industrial firms, our paper looks at banks as borrowers from potentially sophisticated financiers. Indeed, banks are intermediaries and need to borrow in order to invest. While our findings can be applied to the funding choices of industrial firms in general, the model generates stronger and specific effects for banks because banks as borrowers differ from industrial firms in several critical ways.

First, while most industrial projects are illiquid and lack secondary markets in claims, the assets of modern banks in the originate-and-distribute business are often traded in secondary markets with available pricing information and credit ratings. The key contribution of our model is the cross-sectional prediction that differentiates  $s^W$  (socially optimal seniority for short-term wholesale funds) across types of banks depending on their asset- and liability-side characteristics. The model suggests that the dark side of short-term wholesale funding dominates when assets are liquid and relevant public signals on their quality are available. Since liquid secondary markets are more common for bank assets than for industrial projects, our model is naturally more relevant for banks than for industrial firms. For industrial firms, the positive effect of short-term debt seniority on incentives to monitor (Park, 2000) may dominate the negative effect of inefficient early liquidations. For banks, and in particular for those holding arm's length assets with liquid secondary markets, the opposite can be true, as highlighted by the model.

Second, unlike industrial corporations, banks might have little control over the *effective* seniority of short-term wholesale funds. The first-come-first-served sequential service rule in practice and by default gives effective seniority to short-term wholesale funds. Formal seniority is not as important as debt maturity in determining effective

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<sup>7</sup>Von Thadden (1995) shows that the problem of inefficient intermediate liquidations might be best solved by issuing long-term debt in the form of a credit line with a termination clause (so that second-period interest rates is pre-specified ex-ante; the lender cannot bargain based on its information monopoly but could still liquidate a bad project). Similarly, Rajan and Winton (1995) show that covenants (termination clauses) on long-term debt (if they are based on privately available information) may be a better way to induce information acquisition by banks than simple short-term debt.

seniority. Formal seniority steps in only after a bank is legally declared insolvent and redemptions of all debt are suspended. Yet in practice it is very difficult to call a bank's insolvency: unlike industrial firms, the solvency line can be crossed within days if not hours. This allows short-term financiers to withdraw and exit ahead of other creditors, including those with formal seniority, while the bank is insolvent but still liquid.

Finally, the funding structure of banks is relatively less flexible than that of non-financial corporations. Indeed, the optimal contracting literature (e.g., Berglof and von Thadden, 1994) typically presents its results as an optimal funding strategy for a corporation, determining the mix and relative seniority of short- and long-term funding. In contrast, the funding structure of banks is usually quasi-fixed. For example, banks are endowed with a local retail depositor base as the main if not the sole source of long-term funding, which is prohibitively costly to expand. Therefore, there is less scope to choose the optimal structure of short- versus long-term funding.

In fact, for banks, such constraints on contracting with the providers of funds may mean that a socially optimal seniority of short-term wholesale funds  $s^W$  may altogether be impossible to implement when some practical restrictions (i.e., a first-come-first-served constraint) bound possible  $s$  from below. When  $s^W$  cannot be implemented, the banks' use of short-term wholesale funds will always be socially inefficient and associated with the lack of monitoring and excess liquidations. However, the cross-sectional implications of our model will still hold and predict that banks with more arm's length assets will be more affected by the impossibility to implement  $s^W$  than traditional banks with relationship loans.

## 4.2 Arm's length banking, wholesale funding, and financial fragility

The results of our model help explain two stylized facts highlighted by the behaviors of banks in recent years leading up to the recent financial turmoil:

- Why, in practice, do we observe that traditional banks funding mainly relationship loans are less likely to supplement retail deposits with short-term wholesale funds,



while banks holding relatively arm's length assets are more likely to do so? (Berlin and Mester, 1999; Kashyap, Rajan, and Stein, 2002; Berger et al., 2005; Song and Thakor, 2007) Why is the proliferation of securitizations (and thus more arm's length assets on banks balance sheets) closely related to more active use of short-term wholesale funds?

- In the years leading up to the current credit market turmoil, why didn't the wholesale financiers, who had the capacity to monitor, exert sufficient market discipline on banks, and why did they exacerbate liquidity risks once the crisis was on the way?

The analyses of our model provide some new explanations. In our model, the wholesale financier's incentives to incur private monitoring efforts depend on (1) the availability and relevance of the costless public signal and (2) the private costs of liquidating the bank (note also that short-term wholesale funds in practice enjoy more senior creditor access to the liquidated assets). Arm's length assets and relationship loans differ critically in both of these two parameters:

- Arm's length assets typically have some costless public signals available in the form of secondary market prices or credit ratings, and they also have lower liquidation costs. According to our model, wholesale financiers will demand lower interest rates for funding banks holding arm's length assets because of the lower need to incur private monitoring costs and the lower losses associated with premature liquidations.
- Relationship-based loans in contrast have few relevant public signals available and such assets typically have higher liquidation costs. Banks financing relationship loans thus need to pay a higher interest rate to attract short-term wholesale funds to compensate for their private monitoring costs.
- Therefore, banks holding relationship loans typically find it more expensive to use wholesale funding, which answers our first question: why banks holding rela-

tively arm's length transaction loans or securities are more likely to use short-term wholesale funds.

In the years leading up to the 2007 credit market crisis, financial innovations and global liquidity conditions induced banks to acquire more arm's length assets, which have more abundant supply (Dooley, Folkerts-Landau, and Garber, 2008). Banks in turn financed these assets heavily with short-term wholesale funds, because such an asset-liability match reduces funding costs (which is consistent with the predictions of our model). However, our model also shows that such a bank asset-liability match pattern observed in practice, although consistent with the banker's private incentive, is not necessarily consistent with the maximization of social welfare.

Our model explains how the availability of costless but noisy public signals on bank quality reduces the incentives of wholesale financiers to monitor and creates incentives for them to exit based on a negative noisy signal. Our model further shows how this effect is strengthened by their effective seniority over other longer-term sources of funding, such as retail deposits. The analysis of our model is consistent with the behaviors of short-term wholesale funds in many bank failure events, such as Continental Illinois, Northern Rock, IndyMac, and reveal the "dark side" of bank wholesale funding:

- The short-term wholesale funds seemed to have acted based on noisy public signals (sometimes correct, sometimes not) more than private information on individual banks' fundamentals. In the case of Continental Illinois's failure, the collapse of the energy sector and the Penn Square Bank (to which the market suspected Continental Illinois had large exposures) triggered the event. In the case of the Northern Rock failure, the US subprime mortgage crisis caused the freezing of wholesale funding markets across the board, although Northern Rock had no material exposure to the US subprime sector<sup>8</sup>;

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<sup>8</sup>In a letter to *The Economist*, the chairman of Northern Rock, Matt Ridley, wrote: "We were repeatedly advised that liquidity in wholesale markets depended on lending quality: good loan books would continue to attract funding when bad loans began to default. Instead, from August 9, liquidity had dried up across all wholesale markets, making no distinction between loans of different quality, for much longer than even the most extreme forecast."

- When the short-term wholesale funds exit, they typically managed to withdraw ahead of the retail depositors and the authorities, and suffered few losses.<sup>9</sup>

To maximize social welfare, our model suggests that, in order to dampen their incentives to prematurely liquidate banks based on noisy public signals, banks relying on wholesale funding should either make their loans more relationship-based or reduce the effective seniority of the wholesale funds.<sup>10</sup> Such changes in asset-liability arrangement can encourage market discipline and reduce liquidity risks (the benefits of which are not fully internalized by the banks), but will also raise the interest rate demanded by the wholesale financiers, reducing the profits of the banks. Therefore, the self-interest of bankers would not lead them to adopt the socially optimal solution described above, and would instead drive them to adopt the more fragile asset-liability structures that we observe in practice, i.e., banks funding relatively arm's length assets such as mortgage-backed securities are more enthusiastic in complementing their retail deposits with short-term wholesale funds. As discussed in previous section, taxation or deposit insurance premiums that are fairly assessed on banks may help restore the socially optimal incentives.

Note that the model applies also to financial institutions that operate without retail depositors and use wholesale funds only. Conflicts of interest that we describe exist whenever liquidation payoffs are (for contractual or behavioral reasons) skewed across different classes of creditor claimants, e.g., short-term vs. long-term wholesale funds, or collateralized vs. unsecured wholesale funds. For example, Bear Stearns was financed

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<sup>9</sup>Interestingly, the well-publicized retail depositor run on Northern Rock took place only after the bank had already nearly exhausted its liquid assets to pay off the exit of short-term wholesale funds. Marino and Bennett (1999) analyze six major bank failures in the US between 1984 and 1992 and find that uninsured large deposits fell significantly relative to small insured deposits prior to failures. During the New England banking crisis, failing banks experienced a 70 percent decline in their uninsured deposits in their final two years of operation while being able to raise insured deposits to replace the outflow. Billett, Garfinkel, and O'Neal (1998) also find that bank typically raised their use of insured deposits vis-a-vis wholesale deposits after being downgraded by Moody's.

<sup>10</sup>Recall that the effective seniority of wholesale funds reflects a combination many factors: official resolution policies (such as deposit insurance coverage in bank failures, and the treatment of wholesale creditors in central bank bailouts), private contractual arrangements (such as the collateralization of funding and inclusion of withdrawal suspension clauses), and behavioral factors (such as the sluggishness of the retail depositors). Observe that, by default, short-term wholesale financiers do enjoy effective seniority because of the first-come-first-served rule; any deviations from that would require additional contractual arrangements.

by both long-term and short-term wholesale funds, with most of the short-term funds collateralized by marketable assets. Our model explains why secured short-term lenders, being effectively more senior, had insufficient incentives to acquire information on the bank's fundamentals, and were tempted to walk out upon noisy negative news. Had short-term wholesale funds been unsecured or with longer contractual maturity (implying lower effective seniority), their providers would have had higher incentives to monitor and would have been less likely to abruptly stop funding Bear Stearns.

### **4.3 Modelling wholesale financiers**

Our paper used a number of convenient simplifications in modelling wholesale financiers. Most notably we considered a single competitive wholesale financier. It is possible to write a similar model with multiple financiers. The most natural consequence of having multiple financiers would be the scope for coordination failure between them at the refinancing stage (for example, of the type analyzed by Rochet and Vives, 2004). Yet it is important to point out that any coordination failures would only increase the possibility of inefficient liquidations by wholesale financiers. Coordination failures are an additional, yet already well analyzed, facet of the "dark side" of bank wholesale funding. By analyzing a single competitive financier, we turn off coordination failures in our model, and highlight our new and stronger results that inefficient liquidations can occur even in the absence of coordination failures.

For modelling brevity, we have also explicitly ruled out any hold-up at date 1 by pre-determining the date 1 to date 2 interest rate in a manner similar to von Thadden (1995). Competition and interest-rate setting by wholesale financiers can be modelled more fully in the style of Sharpe (1990) and von Thadden (2004). Such enhancements would not affect our key results.

Finally, there are other dimensions of wholesale bank funding markets that were left outside of the scope of this paper. For example, interbank lending often represents a substantial share of wholesale funding of banks. Considering bank inter-linkages within

the "dark side" framework could generate a richer picture of systemic effects, with implications, for example, for peer-monitoring (Rochet and Tirole, 1996) and contagion (Allen and Gale, 2000, Freixas et al., 2000, Acharya and Yorulmazer, 2007). We leave such applications of our framework for future analysis.

## 5 Conclusion

Our paper demonstrates the possibility of opportunistic behaviors by short-term wholesale financiers (where they do not monitor banks and instead withdraw based on noisy public signals) and by banks (where they use such risky wholesale funds).

We show how short-term wholesale financiers can create a "run" on banks based on costless but possibly very noisy public signals about bank asset quality. Their incentives to run may offset or even dominate the incentives to monitor which were highlighted by Calomiris and Kahn (1991). In principle, the risk of wholesale runs can be reduced by assigning them lower creditor seniority. However banks may have contrasting private incentives: we show that the use of senior wholesale funds generates interest rate savings for banks. Moreover, making short-term wholesale funds sufficiently junior may be outright impossible due to the sequential service constraint.

In a bank cross-section, our model predicts that the use of short-term wholesale funds would have more beneficial effects for "traditional" banks holding mainly opaque and non-tradeable relationship loans. In contrast, it is likely that this would create additional risks for "modern" banks holding mostly arm's length assets with readily available, but noisy, public signals on their fundamentals. Examples of such signals include mortgage-backed securities prices, performance of other similar banks, and the health of the housing market. These predictions are consistent with evidence from the credit markets turmoil of 2007–.

The paper discusses a number of policy options, including a risk-based deposit insurance (or taxation) formula that takes into account the differential influence of short-term wholesale funds on different types of banks.

## A Proofs

### Lemma 1

1. To see that  $d\Pi^B/ds > 0$  consider:

$$\frac{d\Pi^B}{ds} = m^W(1-p)sL(D+W) - \frac{d(C(m^W) - m^W(1-p)sL(D+W))}{ds}$$

Use (5) to re-arrange:

$$\begin{aligned} \frac{d\Pi^B}{ds} &= m^W(1-p)sL(D+W) - \frac{d(C(m^W) - m^W C'(m^W))}{dm^W} \frac{dm^W}{ds} \\ &= m^W(1-p)sL(D+W) + m^W C''(m^W) \frac{dm^W}{ds} \end{aligned}$$

Observe that  $m^W(1-p)sL(D+W) > 0$ . Recall that  $C''(m^W) > 0$  and  $dm_W/ds > 0$ . Therefore both terms are positive and  $d\Pi^B/ds > 0$ . QED.

2. To see that  $d\Pi^B/ds > 0$  consider:

$$\begin{aligned} \frac{d\Pi^B}{dW} &= pX - \frac{d(pWR)}{dW} \\ &= pX - \rho - \frac{d(C(m^W) - m^W(1-p)sL(D+W))}{dW} \end{aligned}$$

Use (5) to re-arrange:

$$\begin{aligned} \frac{d\Pi^B}{dW} &= pX - \rho - \frac{d(C(m^W) - m^W C'(m^W))}{dm^W} \frac{dm^W}{dW} \\ &= pX - \rho + m^W C''(m^W) \frac{dm^W}{dW} \end{aligned}$$

Recall that  $pX > \rho$ . Also recall that  $C''(m^W) > 0$  and  $dm_W/dW > 0$ . Therefore  $d\Pi^B/ds > 0$ . QED.

**Lemma 2** Points 1 and 2 were explained in text. Point 3 requires that  $m^W$  and  $m_{Li}^W$  are continuous at  $s^W$ . This is easy to verify by applying  $[p - \theta p] pWR = s^W L(D+W)$  from (12) to  $m^W$  (5) and  $m_{Li}^W$  (14). QED.

**Proposition 3** We construct an example of parameters under which a bank chooses to assign short-term wholesale financiers creditor seniority  $s = 1$  instead of  $s = s^W$ . This is sufficient to prove existence.

1. Consider a function  $C(m)$  which is almost horizontal until the close environ of certain  $\bar{m}$ , is increasing in that small environ, and is almost vertical after that. This makes the wholesale financiers' choice of monitoring always very close to  $\bar{m}$ . Such a function allows us to make the effects on seniority on  $m$  secondary to the effects of seniority on liquidation decisions and interest rates.

2. We further take:

- $\bar{m}$  and  $C(\bar{m})$  to be both close to 0
- liquidation value  $L$  to be the highest possible:  $L = pW$
- precision of signal  $\theta$  to be the highest possible:  $\theta = \theta^* = 1 - \frac{L}{pX} = 1 - \frac{W}{X}$

3. Under these conditions:

$$\begin{aligned} R(s^W) &= \frac{W\rho + C(m^W) - m^W(1-p)sL(D+W)}{Wp} = \frac{\rho}{p} \\ s^W &= \frac{(1-\theta)pW}{L} = \frac{W\rho}{Xp} \end{aligned}$$

4. We can substitute everything into the inequality in question:

$$\begin{aligned} (1-p)L(D+W)(1-s^W) &> \Delta \\ (1-p)pW(D+W) \left(1 - \frac{W\rho}{Xp}\right) &> p\frac{W}{X}(1-p) \left[ D(X-1) + W \left(X - \frac{\rho}{p}\right) \right] \end{aligned}$$

5. Arranging terms gives:

$$\begin{aligned} X(D+W) &> D(X-1) + WX \\ D &> 0 \end{aligned}$$

which always holds. QED.

6. 6. As a side-line, note that the inequality  $(1-p)L(D+W)(1-s^W) > \Delta$  does not necessarily hold under milder condition. For example, it does not hold for  $L$  close to 0, for  $\theta$  close to  $\theta^W$  (which would make  $s^W = 1$ ).

**Lemma 3**

1. Consider similar parameter values as those in the proof of Proposition 2. Then an unregulated bank chooses  $W = 1 - D$  and  $s = 1$ . Then the social welfare is

$$\Pi_{Liq} = [p[p + \theta(1-p)]X + (1-p)L] - 1$$

2. The social welfare under  $W$  equal to 0 is

$$\Pi^+ = D(pX - 1)$$

3. Now take  $D$  is close to 1, so that  $W$  (and hence  $L$ ) are both close to 0 in the non-zero case. Then  $\Pi^+ > \Pi_{Liq}$  reduces to

$$pX > p[p + \theta(1-p)]X$$

QED



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